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Standard Guide for General Principles of Resilience¹

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1. Scope

1.1 This guide covers general principles related to the resilience of systems, including natural and anthropological systems.

1.2 Resilience is defined by four general principles: planning and preparation, adaptation, withstanding and limiting impacts, and recovery of operations and function. This guide covers the fundamentals for each of the general principles.

1.3 This guide recognizes that, in applying principles of resilience, decision makers often balance opportunities and challenges, as well as the safety and risk associated with each of the general principles and their interdependence.

1.4 This guide recognizes that improved resilience may result from a variety of sources and potential solutions. Solutions and their associated impacts can span economic, physical, environmental, health and wellness, ecological, and other human aspects related to individuals, organizations, social systems, physical systems, and natural systems.

1.5 The general principles identified in this guide are applicable to all types of systems, the boundaries of which are defined by the user based upon the system functions, uses, and impacts, as well as other natural, social, economic, or physical constraints for the specific situation.

1.6 Applying the principles in this guide will require informed assessment and practical experience to determine if system resilience goals are advanced or achieved through application of the four principles and meeting project requirements.

1.7 This guide acknowledges that the various contexts in which a system is used or operates directly affects its resilience.

1.8 This guide recognizes that one or more components make up systems, requiring evaluation of each component individually, as well as being part of the relevant system, and in relationship to relevant externalities.

1.9 This guide recommends four general principles to inform planning and design processes; it does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with informed judgment.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

C1145 Terminology of Advanced Ceramics

E2114 Terminology for Sustainability

E2135 Terminology for Property and Asset Management

E2432 Guide for General Principles of Sustainability Relative to the Built Environment

E2921 Practice for Minimum Criteria for Comparing Whole Building Life Cycle Assessments for Use with Building Codes, Standards, and Rating Systems

E3027 Guide for Making Sustainability-Related Chemical Selection Decisions in the Life-Cycle of Products

3. Terminology

3.1 *Definitions*—For terminology where the definition is defined in another standard:

3.1.1 *built environment, n*—refer to Guide E2432.

3.1.2 *durability, n*—refer to Terminology C1145.

3.1.3 *repairable, n*—refer to Terminology E2135.

3.1.4 *risk, n*—refer to Guide E3027.

3.1.5 *risk assessment, n*—refer to Terminology E2135.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.6 *service life*, *n*—refer to Practice E2921.

3.1.7 *sustainability*, *n*—refer to Terminology E2114.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *disruptive event*, *n*—an event over a short timeframe that may impact a system to a degree that the system is unable to perform its intended function or service.

3.2.1.1 *Discussion*—Disruptive events may be caused by natural hazards (for example, an earthquake, fire, floods, or pandemic), technological hazards (for example, oil spill), or human-caused hazards (for example, an attack).

3.2.2 *resilience*, *n*—the ability to prepare for anticipated hazards, adapt to changing conditions, to withstand and limit negative impacts due to events, and to return to intended functions/services within a specified time after a disruptive event.

3.2.2.1 *Discussion*—Resilience is not durability nor sustainability but may include those concepts.

3.2.3 *resilient*, *adj*—able to withstand or recover from disruptive events or stressors.

3.2.4 *stressor*, *n*—a changing condition that negatively affects system performance over time.

3.2.4.1 *Discussion*—Slowly changing conditions may be environmental (for example, the effects of climate), physical (for example, degradation of transportation or water systems or increased demands on existing systems), or social (for example, lack of training or educated workforce or chronic food or water shortages).

3.2.5 *system*, *n*—an assembly of interconnected natural and anthropological components that serve a function or provide a service at or within defined boundaries.

3.2.5.1 *Discussion*—An anthropological system can be physical (for example, building, utility network) or social (for example, education, financial). Both anthropological and natural (for example, wetland, forest) systems can be composed of an interdependent set of systems.

4. Significance and Use

4.1 Every system is subject to disruptive events and stressors. Events and stressors can occur at all life-cycle stages and affect systems in multiple ways and on a range of scales. It is imperative to define and understand the nature of the events and stressors that may affect a system in order to address the opportunities and challenges presented.

4.2 A resilient system is better able to withstand an anticipated disruptive event or stressor.

4.3 Knowledge from historic disruptive events can aid in the design of system resilience. However, assumptions based on historical events may not be indicative of future conditions or future system operations, or they may not be consistent with design criteria in codes and standards. Systems can be designed to withstand and limit damage and support health and safety; stressors and recovery of function can often be more robustly addressed in initial system design practice. Advancing resilience requires addressing all principles of resilience for applicable events and stressors during the design process and life of the system.

NOTE 1—Design practice is influenced by codes, standards, federal regulations, and other applicable industry best practices. Both resilience, particularly recovery of function and services, and stressors, are new concepts for design practice of many systems, and guidance is evolving.

4.4 This guide provides general guidance but does not prescribe a specific course of action.

4.5 This guide is intended to inform those associated with creating or managing a system when considering its resilience. This could be product development teams, designers, or assessment teams.

4.6 The general principles of resilience are interrelated. However, to facilitate clarity, they are discussed individually as much as possible.

4.7 The general principles in this guide are intended to identify the required performance of more resilient systems and to assist users in making decisions that advance resilience.

4.8 The general principles identified in this guide are intended to inform the development and refinement of tools and standards that qualify and quantify resilience.

4.9 This guide, in covering general principles, is intended to be a basis for the creation of more specific documents on more specific topics.

5. The General Principles

5.1 The four principles are interdependent as shown in Fig. 1. A higher level of resilience can be achieved by addressing all four resilience principles, from planning through recovery, as decisions at each stage or phase of resilience have an influence or impact on the other stages or phases.

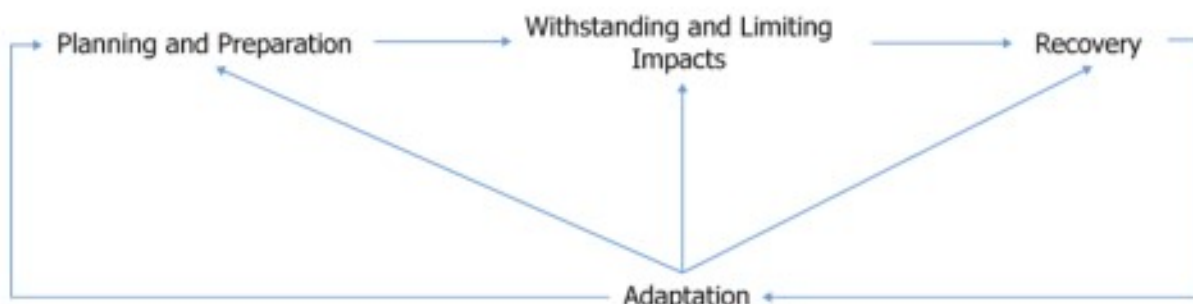


FIG. 1 Interdependency of Principles and How They Lead to Resilience

5.2 Planning and Preparation—Planning and preparation involve identifying measurable system performance requirements, goals for improved resilience, relevant hazards and stressors for the system(s) under consideration, interdependencies, and engagement of relevant stakeholders who have a role or an interest in the operation or function of the system.

5.3 Adaptation:

5.3.1 Adaptation addresses the performance of the system for future disruptive events or stressors.

NOTE 2—Systems may need to continue to perform the same function over a planned period of time during which changes in disruptive events or stressors may occur. For example, a house may need to be elevated to accommodate rising water levels caused by sea level rise.

NOTE 3—Systems may have new uses following a disruptive event, where a system function is altered to meet another purpose. For example, a public meeting area or school may serve as a shelter during or after events when needed.

5.4 Withstanding and Limiting Impacts—Withstanding and limiting impacts is the ability of a system to resist the loads and effects of a disruptive event or stressor such that the system remains able to perform with respect to its intended function. Any damage should not interfere with system functions.

5.5 Recovery—Recovery occurs over a period of time that can be divided into stages or phases associated with resumption of services and functions, possibly with temporary measures, and repairs and construction to restore the full functional performance and physical condition of the system. Recovery may include improvements to the functional performance or condition of the system, adaptation for new or additional functions, or to address future events or stressors.

6. Determining the Goals and Boundaries of the System

6.1 To fully examine and execute the principles of resilience, the user should define the resilient goals for the system performance.

6.2 The intended functions or services of the system, as well as intended alternate uses, should be defined for the system with the input of all stakeholders, including end users.

6.3 The boundaries of the system should consider dependencies on and by other systems, such as energy flows or material flows. Additionally, cost and external factors relevant to the system under consideration (for example, natural boundaries, political boundaries) may be considered.

6.4 The boundaries of the system should be considered throughout different periods of operation, such as during normal operations, operations during a disruptive event, and operations during periods of degraded function or recovery.

6.5 Once the system's boundary and resilient goals are specified, the effects of disruptive events on the system are evaluated based upon the four principles.

6.6 The resilience of a system may depend on the resilience of its components, including reliance on or interdependence with other systems.

7. The Planning and Preparation Principle

7.1 For resilience, the planning and preparation principle includes establishment of system resilient goals, engagement of stakeholders, and identification of disruptive events and stressors. The following points should be considered:

7.1.1 Establishment of system resilience goals that are measurable. A resilience planning process should specify goals of the desired system performance for functional and operational levels after a disruptive event. These levels of performance may be informed by system requirements, as well as external interdependencies or code/regulatory requirements.

7.1.2 Engagement of stakeholders for expected performance of the system at hand. In planning for system resilience and meeting performance goals, other impacted systems, organizations, and those that affect the ability of a system to function and deliver service (for example, interdependencies) as well as end users should be identified. The input of these stakeholders on the performance goals and resilience plans should be obtained at key points in the planning process.

7.1.3 Identification of disruptive events and stressors. Identify those disruptive events and stressors that are likely to occur over the system's life cycle and with sufficient potential impacts. Once the types of disruptive events are selected, the users should identify the magnitudes or levels of hazard to be considered in the planning process.

NOTE 4—For example, the operators of a water treatment facility should consider the hazards or stressors that could affect assets under the control of the facility operator, and dependencies on other systems. These assets could include treatment facilities, distribution systems (for example, pipelines), other infrastructure dependencies (for example, electrical services, transportation infrastructure), consumable supply chains (for example, treatment chemicals), and personnel requirements (for example, skilled personnel, contractors for repair).

7.1.4 The following three levels of disruptive events may be considered:

7.1.4.1 Routine level disruptive events (that is, occur regularly, continued operation or function of the system is expected).

7.1.4.2 Design level disruptive events (that is, based on codes and standards, with a small likelihood of occurring during the system service life, with adequate design and construction, minor loss of operation or degradation of function is expected with rapid restoration possible).



7.1.4.3 Extreme level disruptive event (that is, rare disruptive events that infrequently occur (less frequently than the design level) and may result in significant damage, loss of operation, or societal consequences due to direct damage or damage on other interdependent systems).

8. The Adaptation Principle

8.1 Systems may need to adapt in order to remain resilient. Failure to adapt, be it quickly to respond to an event or long-term to adapt to changes in user requirements, stressors, or external factors (for example, evolving environmental conditions, or societal conditions), make a system less resilient.

8.2 Established systems that cannot be modified to changing user needs are considered less adaptive because they may become more sensitive to stressors or to a disruptive event. Future uses, both in future extreme disruptive events and normal conditions, therefore, should be considered when designing the adaptive capacity of a system.

8.3 Adaptation over time (responding to stressors), and for alternate uses following disruptive events, can be included in the planning and preparation phase with adequate definition.

9. The Withstanding and Limiting Impact Principle

9.1 The ability of a system to withstand and limit the impacts from a disruptive event is determined through identification of resilience goals and metrics for measuring performance, identification of possible hazard events and stressors over the system's service life, use of resilience performance criteria for design, the system's performance during events, and post-event ability to meet the system's intended functions.

9.2 The resilience performance goals and expected performance of the system should be used in analyses and risk

assessments to guide and prioritize the design for the identified hazards and stressors.

NOTE 5—For example, a building designer may identify that possible hazard events for a building in a specific region are wildfires and high winds (tornadoes or hurricanes). The building designer needs to consider both events when evaluating its performance and ability to meet resilience goals as one or both events may occur during its service life.

9.3 Systems where the impact is controlled through design can often recover more rapidly and, therefore, be considered more resilient, especially if the impacts can be remediated quickly after the disruptive event.

10. The Recovery Principle

10.1 Systems that recover along specified timeframes, or along other user-specified performance parameters, are considered more resilient than those that require long-lead times for repair or are unpredictable in their capacity to be restored. However, rapid restoration or repair may not be a requirement for all system components. Some system components are designed to fail to meet primary system functions and are not needed for a minimal or functional level of recovery.

10.2 Rapid recovery, when it includes repair, includes readily repairable system components and restorable materials where applicable, given sufficient levels of personnel and availability of materials, adequate supply chain and energy flows in conjunction with or independent of the ability to withstand the disruptive event.

10.3 A system design should include recovery of function for its design hazard events to achieve the specified resilience performance. System design includes evaluation of all components performing individually and as part of the system.

11. Keywords

11.1 adaptation; recovery; resilience; resiliency; resilient

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL RESOURCES AND REFERENCES FOR CONSIDERATION IN ADDRESSING RESILIENCE OF SYSTEMS

X1.1 Federal Emergency Management Agency: <https://www.fema.gov/resilience>.

X1.2 *Guidance for Designing Health and Residential Care Facilities that Respond and Adapt to Emergency Conditions*, The Facility Guidelines Institute, March 2021.

X1.3 ISO/TR 22370:2020 Security and resilience — Urban resilience – Framework and principles, International Organization for Standardization, Geneva, Switzerland.

X1.4 ISO 22392:2020 Security and resilience — Community resilience — Guidelines for conducting peer reviews, International Organization for Standardization, Geneva, Switzerland.

X1.5 ISO/TS 22393:2021 Security and resilience — Community resilience — Guidelines for planning recovery and renewal, International Organization for Standardization, Geneva, Switzerland.

X1.6 ISO 22396:2020 Security and resilience — Community resilience — Guidelines for information exchange between organizations, International Organization for Standardization, Geneva, Switzerland.

X1.7 NIST Community Resilience Program, *Community Resilience Planning Guide for Buildings and Infrastructure Systems - Volume 1*, Special Publication (NIST SP) 1190v1, Gaithersburg, MD, May 2016, <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1190v1.pdf>.

X1.8 NIST Community Resilience Program, *Community Resilience Planning Guide for Buildings and Infrastructure Systems - Volume II*, Special Publication (NIST SP) 1190v2, Gaithersburg, MD, May 2016, <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1190v2.pdf>.

X1.9 NIST Community Resilience Program (2020), *Community Resilience Planning Guide for Building and Infrastructure Systems: A Playbook*, NIST SP1190GB-16, Gaithersburg,

MD, <https://doi.org/10.6028/NIST.SP.1190GB-16>.

X1.10 Reid, R. L., "How to Make Infrastructure More Resilient Against Climate Change," *Civil Engineering Magazine*, January/February 2022, <https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/issues/magazine-issue/article/2022/01/how-to-make-infrastructure-more-resilient-against-climate-change>.

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